Observing the Ocean and Earth with

SMART CABLES

SMART Cables: Update and Tsunamis

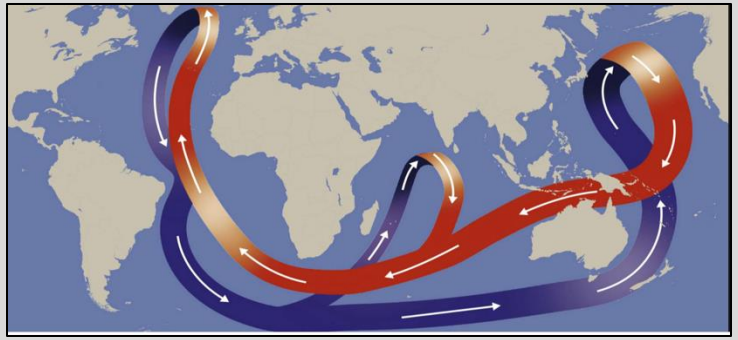
Bruce M. Howe
JTF SMART Cables Initiative
International Programme Office
University Hawai'i at Mānoa

PTWS Joint WG2-TT-ISN and TT-FOO
16 September 2024
Honolulu, Hawaii

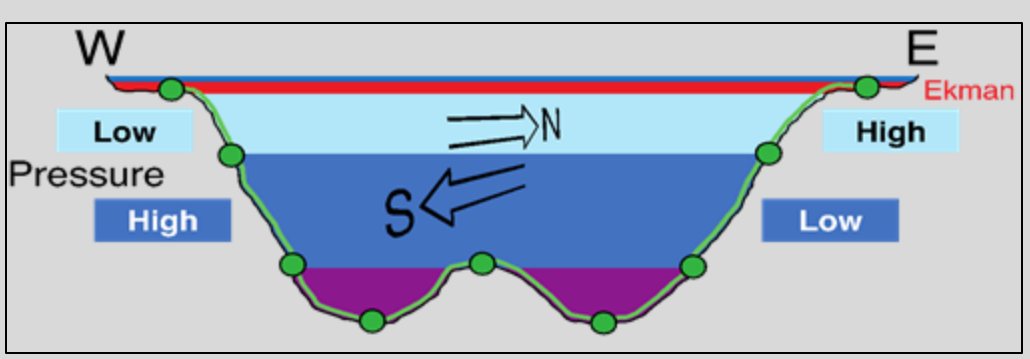
ITU/WMO/UNESCO-IOC JTF SMART Cables

United Nations effort uniting science with the telecom industry to observe the oceans and Earth

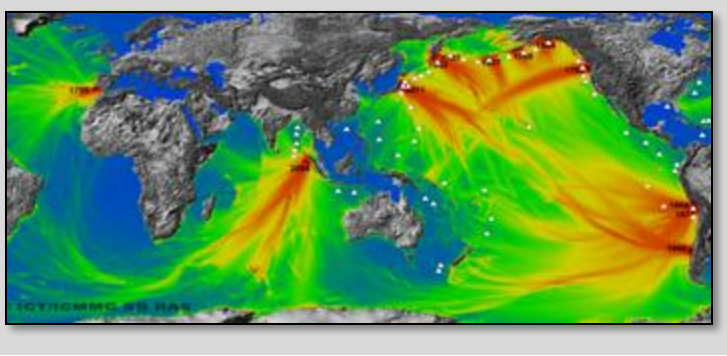
Ocean general circulation – all scales



Climate Change



Ocean heat and circulation



Earthquakes and Tsunamis

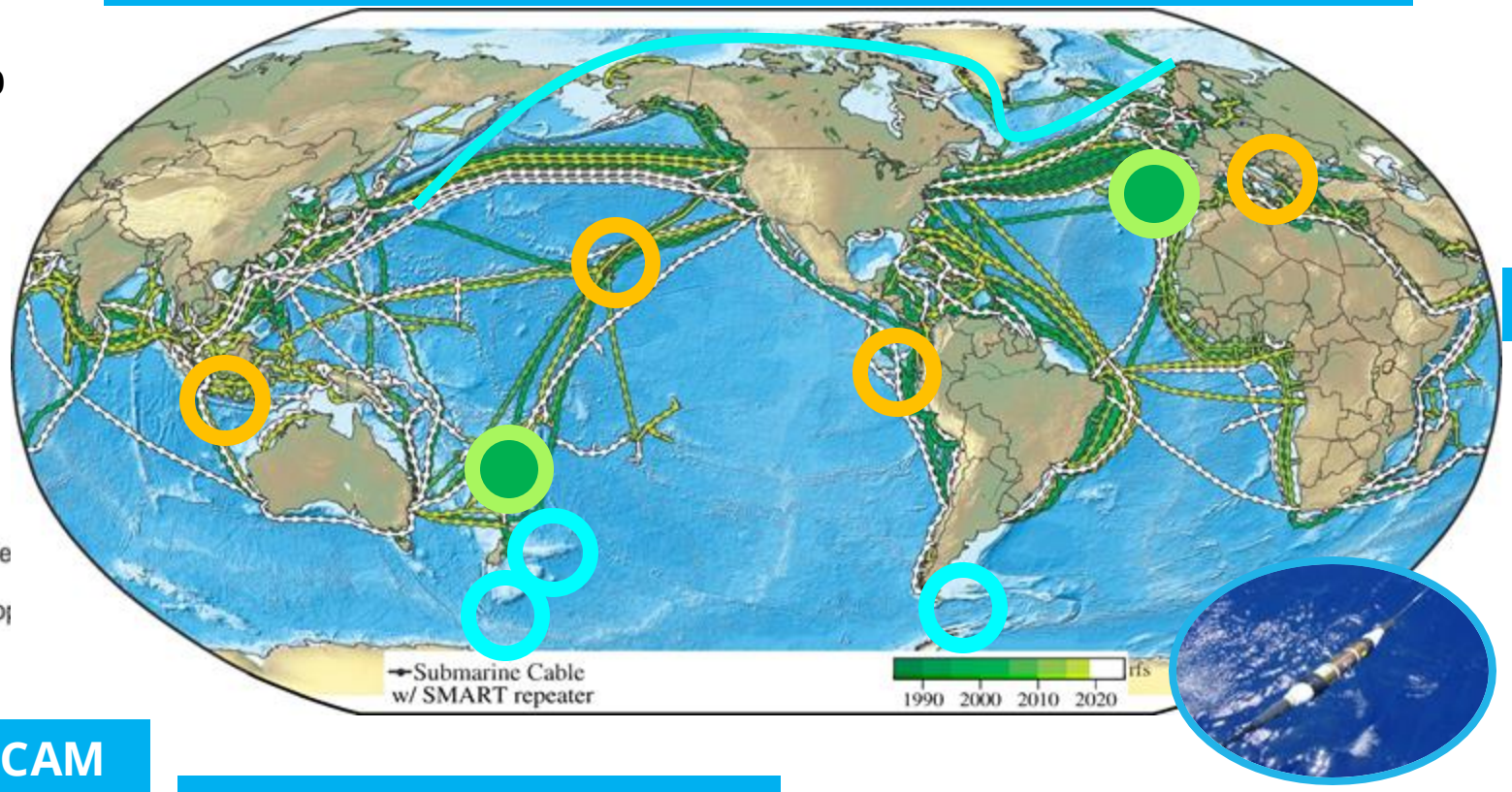
Sea Level Rise

Climate Change and Disaster Risk Reduction

Global Array for Climate, Oceans, Sea Level, Earthquakes, Tsunamis

Create a Planetary sensor, power, Internet network

1st order addition to Ocean-Earth observing system



Share submarine cable infrastructure
Telecom + science
↓€$

NO Interference

1.4+ GM
~20,000 repeaters
20 year refresh

repeaters ~100 km

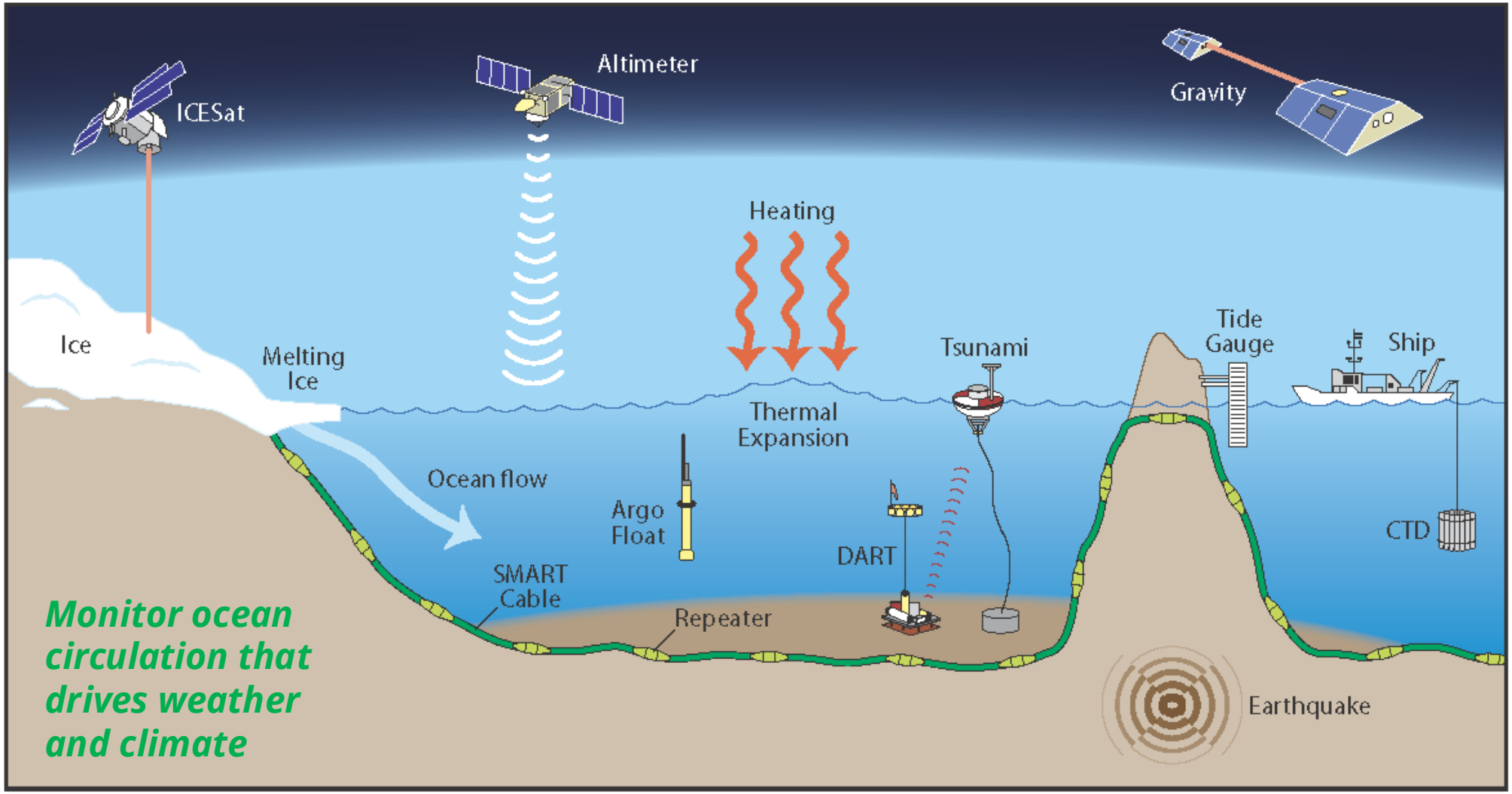
2021 2030 United Nations Decade of Ocean Science for Sustainable Develop

SMART Atlantic CAM and Tamtam V-NC Funded, install 2026

Know the environment protect the network

Bottom temperature, pressure, seismic motion

Ocean + Climate change – Long term Observation



SMART Cables measure Essential Ocean Variables:
Temperature, Pressure; Seismic motion + ...

SMART Technical Solution

Shared Cable Infrastructure: Telecom + Science

Repeater

Sensor module on bottom
(INGV Wet Demo)

Existing Technology

No Interference

Sensors:

- Temperature
- Pressure
- Seismic

Key point:

- Essential Ocean Variables, Global Ocean Observing System

Climate Change solution (SMART* technology)

ASN, the key partner for
undersea data acquisition
With scientific sensors

Commercially available

Separate modules:

- **+ Variable spacing**
- **+ More flexible sensors**
- **– ⬆ $/unit**

Key applications

Risk monitoring

- Earthquake detection
- Tracking of tsunami wave
- Tsunami warning

Scientific observation

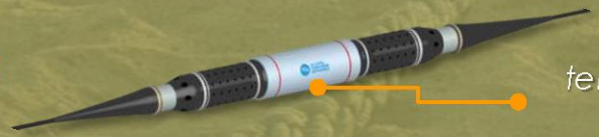
- Sea bottom movements
- Sea level rise
- Slow drift of sea bottom temperatures
- Sea water currents by temperature & pressure combination

ASN solution based on CC-Nodes

New generation of submarine networks integrating sensors for Climate Change observation

dual use (telecom + CC) & dedicated CC systems

CC-NODE



temperature | accelerometer
pressure | specific sensors

ASN, part of the Ocean Decade

"Science we need for the ocean we want"

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

First SMART projects planned for 2025 / 2026

- South Pacific
- Atlantic
- Asia

* *Scientific Monitoring And Reliable Telecommunications*

SMART Cables in WMO and IOC: GOOS

GOOS *in situ* networks [1]	Implementation	Data & metadata			Best practices [6]	GOOS delivery areas [7]		
	Status [2]	Real time [3]	Archived high quality [4]	Metadata [5]		Operational services	Climate	Ocean Health
Ship based meteorological - SOT	★★☆	★★☆	★★☆	★★½	★★☆	✓	✓	
Ship based oceanographic – SOT	★★½	★★½	★★★	★★☆	★★★	✓	✓	
Repeated transects - GO-SHIP	★★★	Not applicable	★★★	★½☆	★★★		✓	✓
Sea level gauges - GLOSS	★★½	★★☆	★★★	½☆☆	★★☆	✓	✓	
Time series sites - OceanSITES	★★☆	Not applicable	★★½	★☆☆	★★☆		✓	✓
Coastal Moored buoys – DBCP	★★★	★★★	★★★	★☆☆	★★½	✓	✓	✓
Tsunami buoys - DBCP	★★½	★★★	★★★	★★☆	★★★	✓		
Tropical moored buoys - DBCP	★★½	★★★	★★★	★★★	★★☆	✓	✓	✓
HF radars	★½☆	★½☆	½☆☆	½☆☆	★★★	✓	✓	
Drifting buoys - DBCP	★★★	★★½	★★½	★★½	★★★	✓	✓	
Profiling floats - Argo	★★★	★★★	★★★	★★★	★★½	✓	✓	
Deep & biogeochemistry floats - Argo	★½☆	★★½	★★½	★★★	★★☆	✓	✓	✓
OceanGliders	★½☆	★★☆	★☆☆	★★☆	★★☆	✓	✓	✓
Animal borne sensors - AniBOS	½☆☆	★☆☆	★★☆	½☆☆	★★☆	✓	✓	✓

Existing GOOS Networks

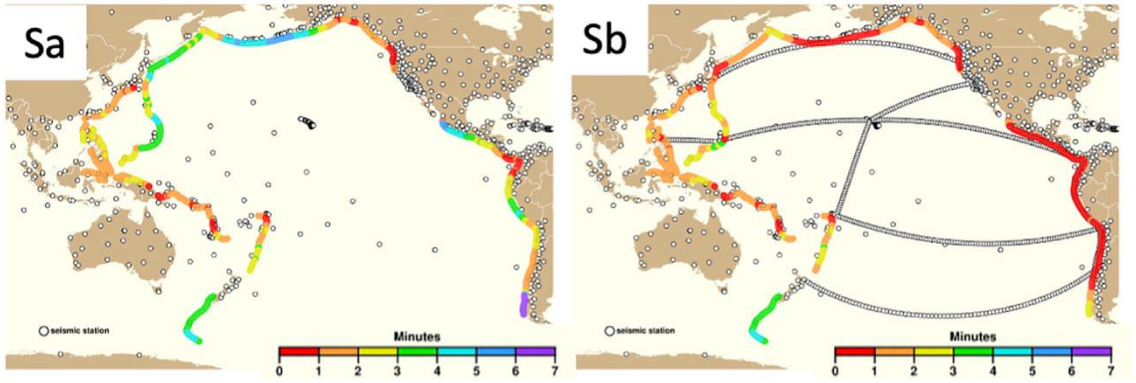
SMART Cables

2024: SMART Cables is a GOOS Emerging Network

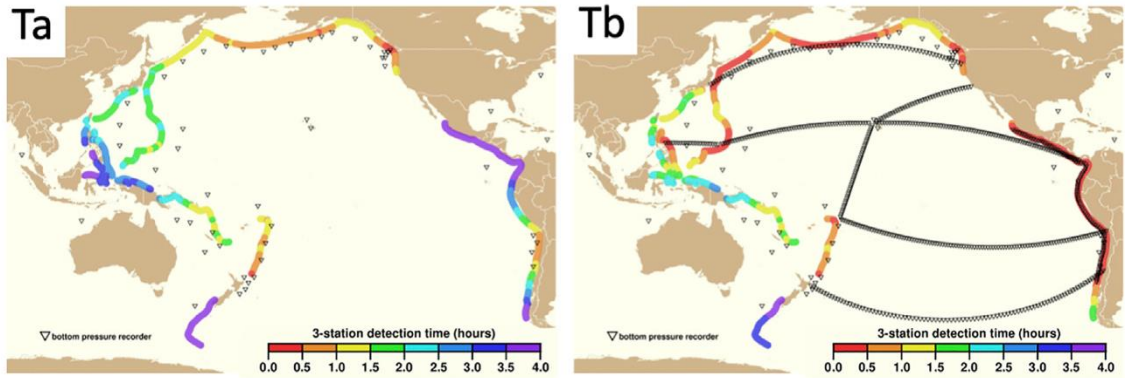
GOOS Report Card 2023

Earthquake and Tsunami Warning

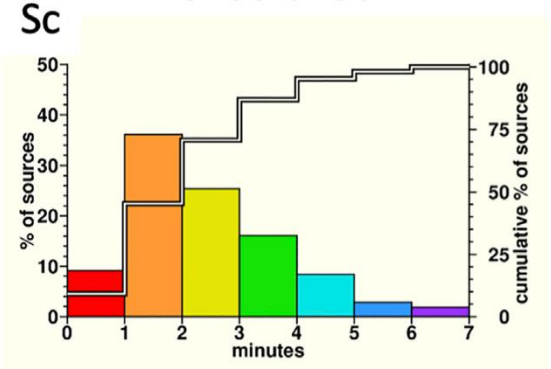
Seismic



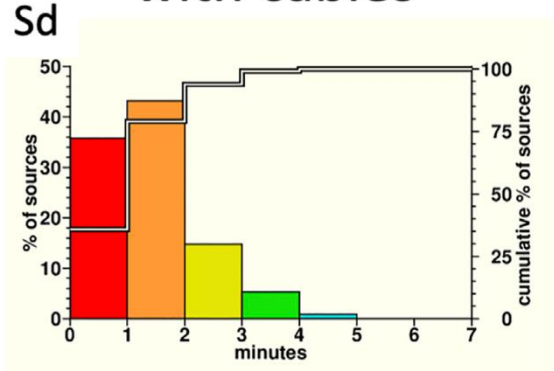
Tsunami



No cables

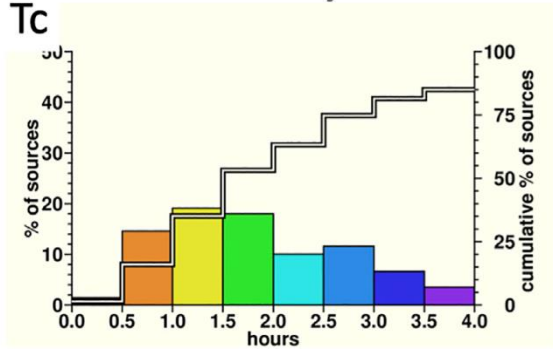


with cables

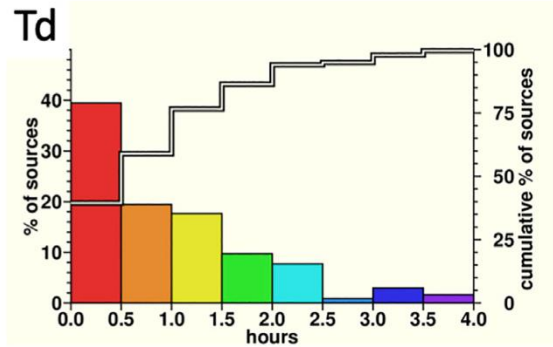


0 - 7 minutes

BPR only



with cables



0 - 4 hours

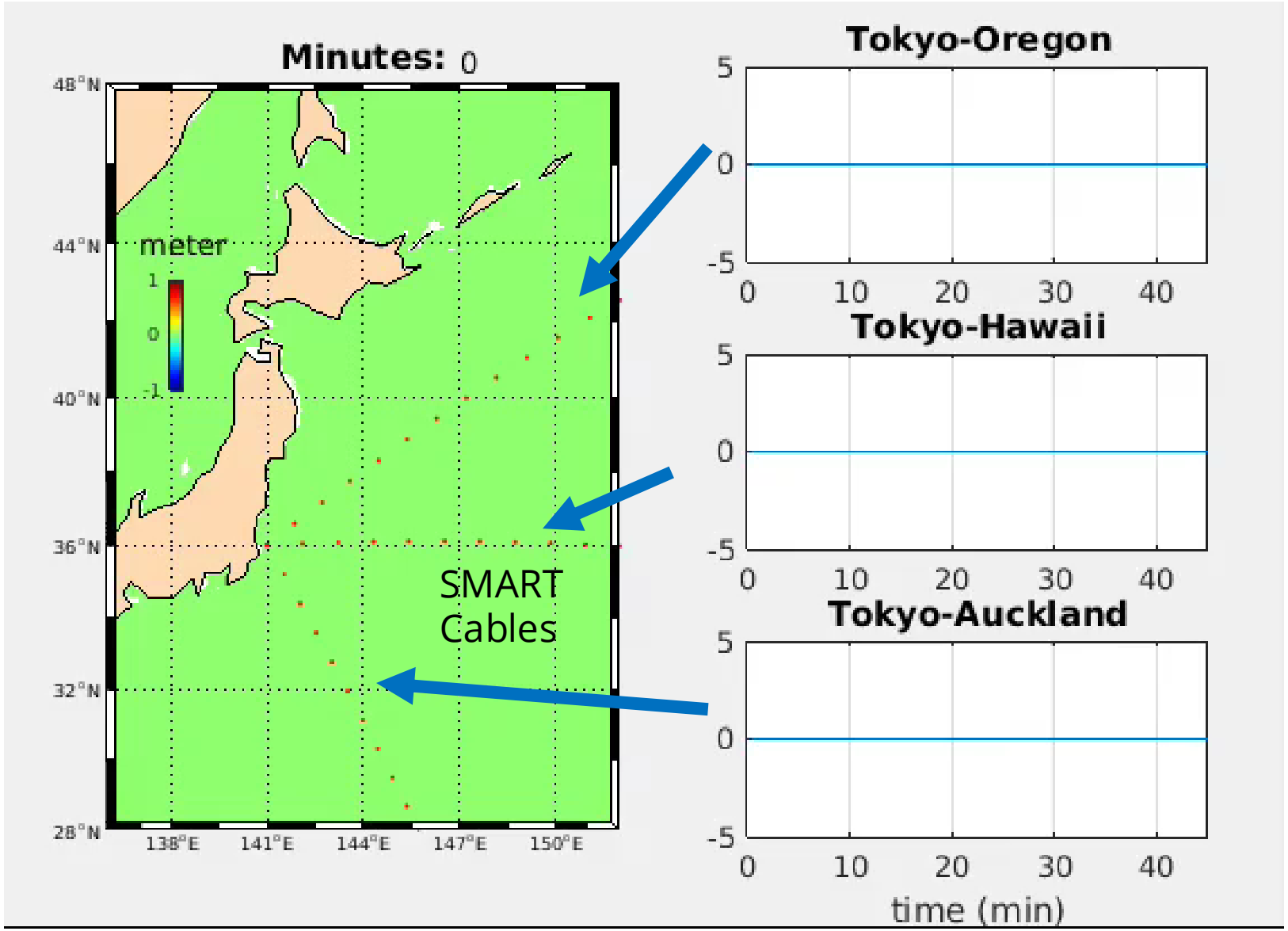
Simple travel time calculations, assumed source locations (trenches)

Nate Becker, PTWC

Earthquake detection time reduced
2.44 to 1.42 min, ~42%.

Time dropping from
2.4 to 1.0 h, ~ 57%

Simulation – Tsunami Detection



Each dotted line represents pressure and seismic sensors along cable

Realtime!

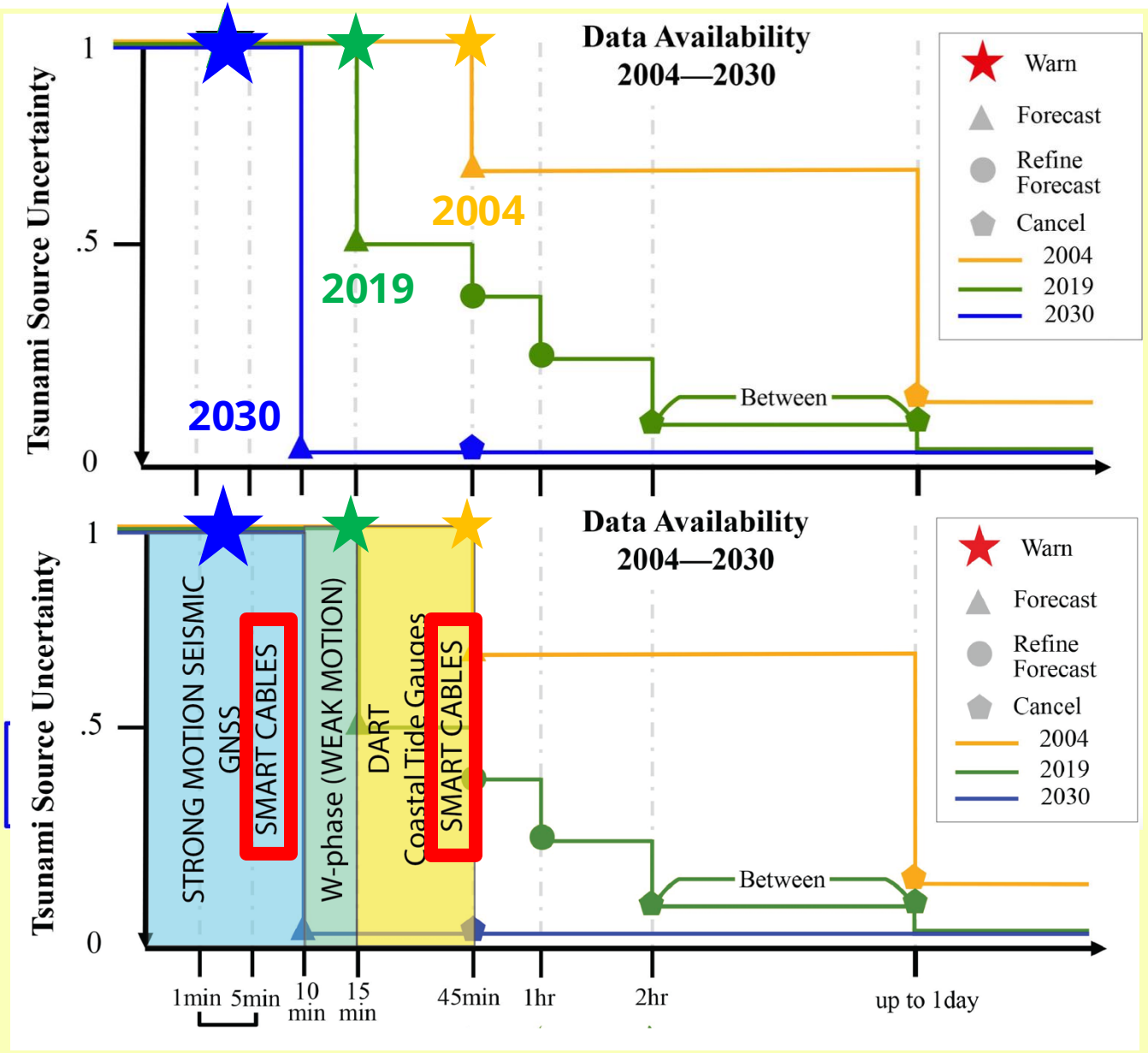
Reliable!

In situ

Tony Song,
JPL/CalTech

Improvement in Early Warning (SMART, GNSS)

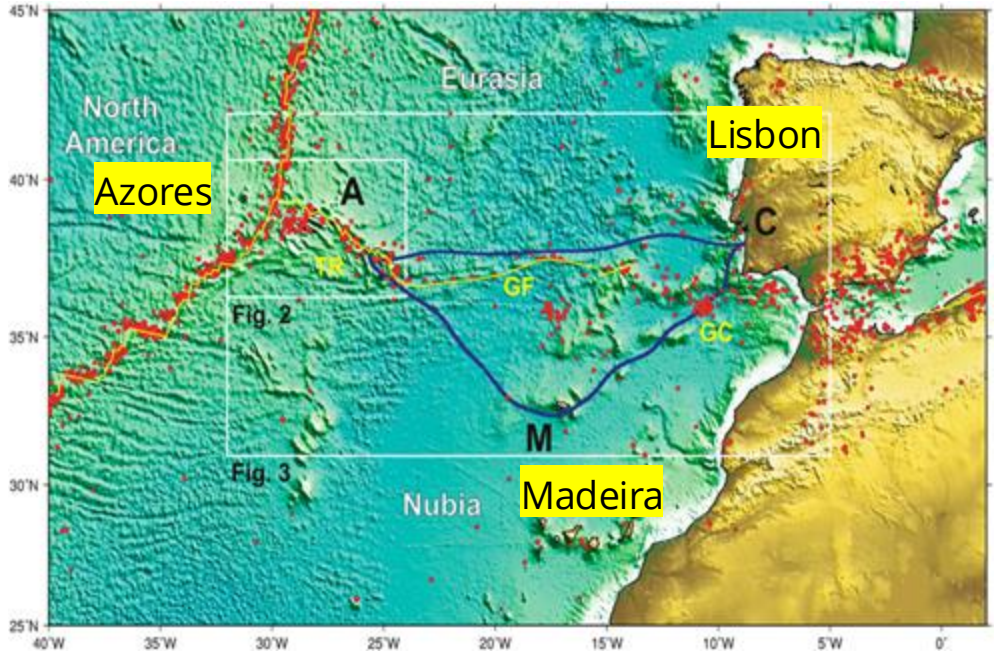
UN Ocean Decade Goal:
Integrate SMART Cable technology into innovative early warning systems



2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Funded SMART Cable Systems

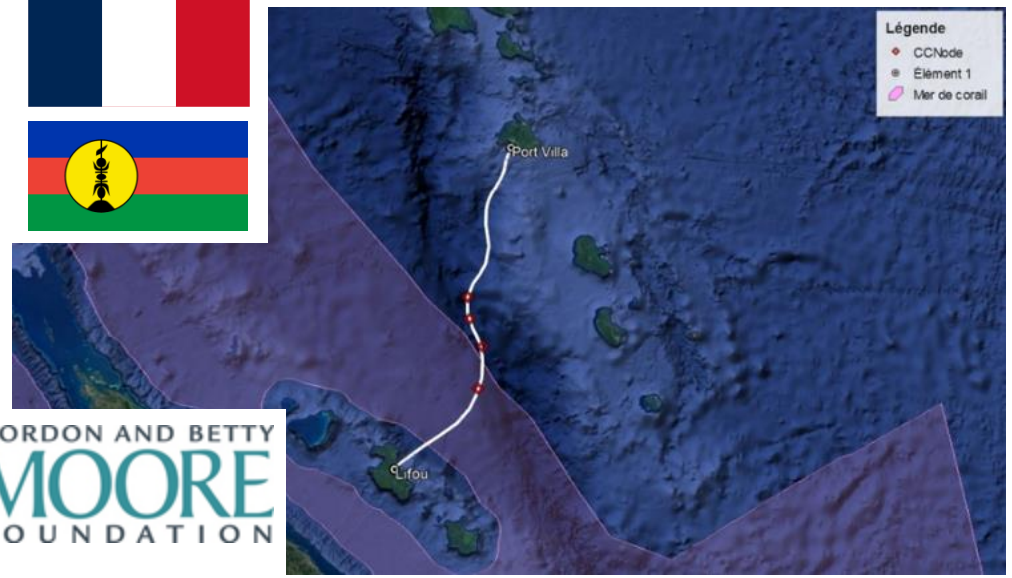
Portugal SMART Atlantic CAM



- 3700 km, ~20 SMART modules
- Gov't €154M. EU support €56M
- SMART 15% ➔ €22M ~ €2/citizen/25 y
- ~ 2 Tsunami buoys, 25 year (unreliable, no seismic, not real time)

Contracts signed
ASN
RFS 2026

TAMTAM SMART Cable System

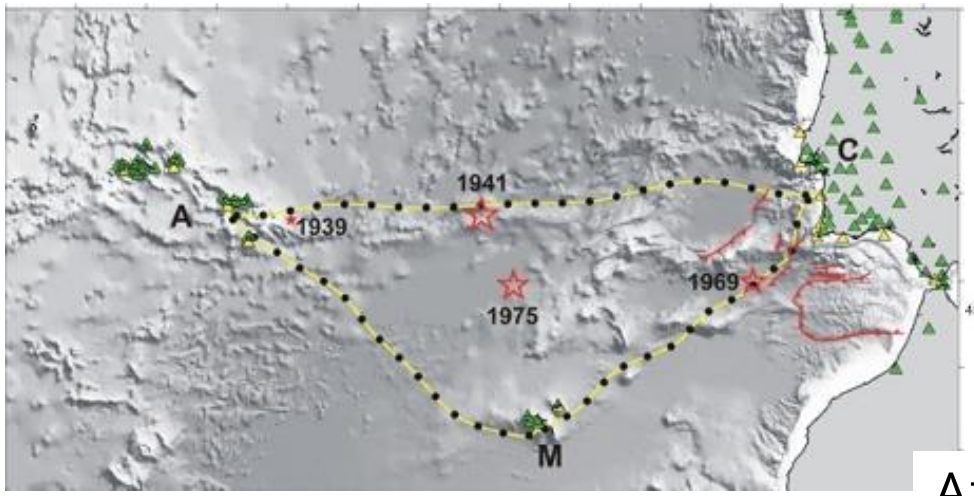


- 450 km long, 4 SMART modules
- France funding SMART (telecom: AFD, ADB)

- 25+ year life, reliable, low lifetime cost
- Leverage $5B/y industry, 170 y

Optical Fiber Sensing in both

Portugal – Continent/Azores/Madeira (CAM)



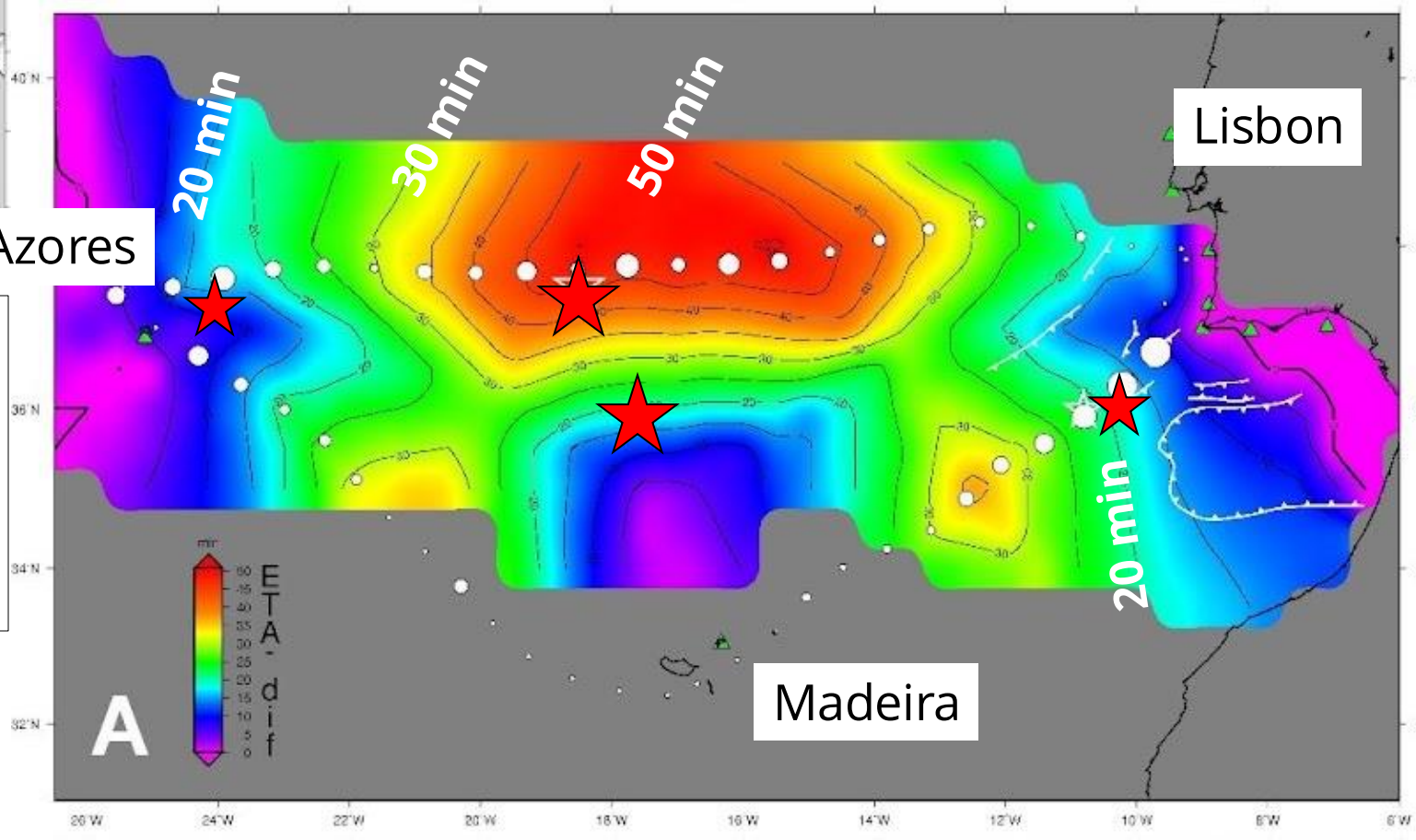
CAM submarine cable (SMART repeaters every ~70 km)

Green triangles - seismic stations (Instituto Português do Mar e da Atmosfera (IPMA)

Yellow triangles - coastal tide-gauges monitored (IPMA)

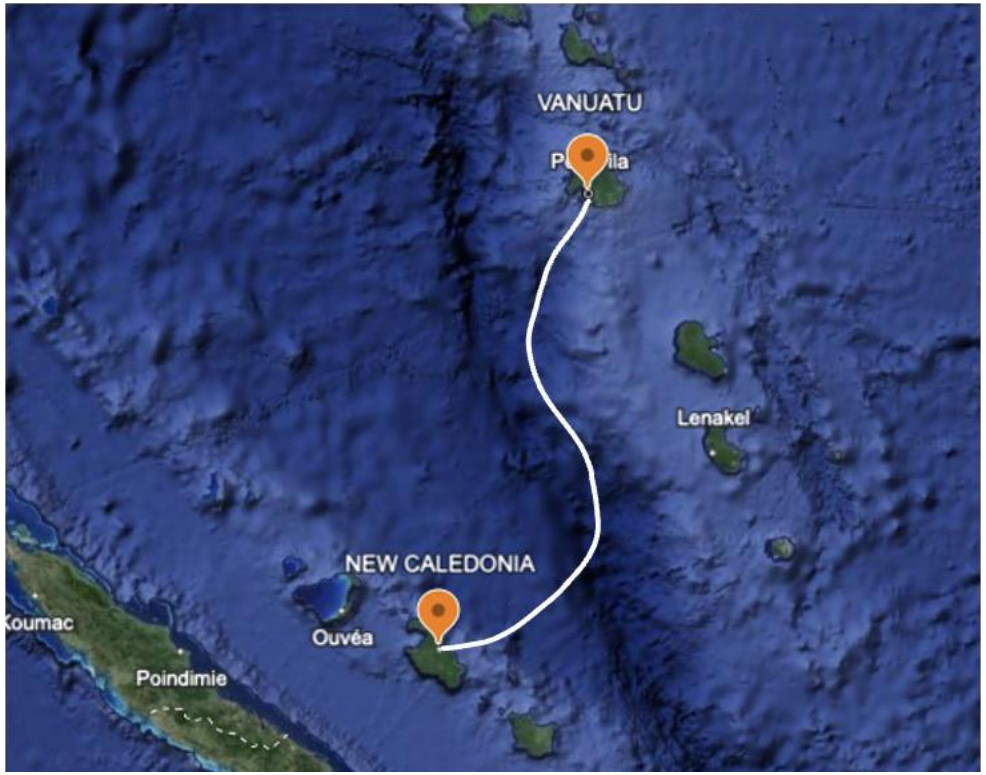
Red stars - M > 7.7 large tsunamigenic earthquakes

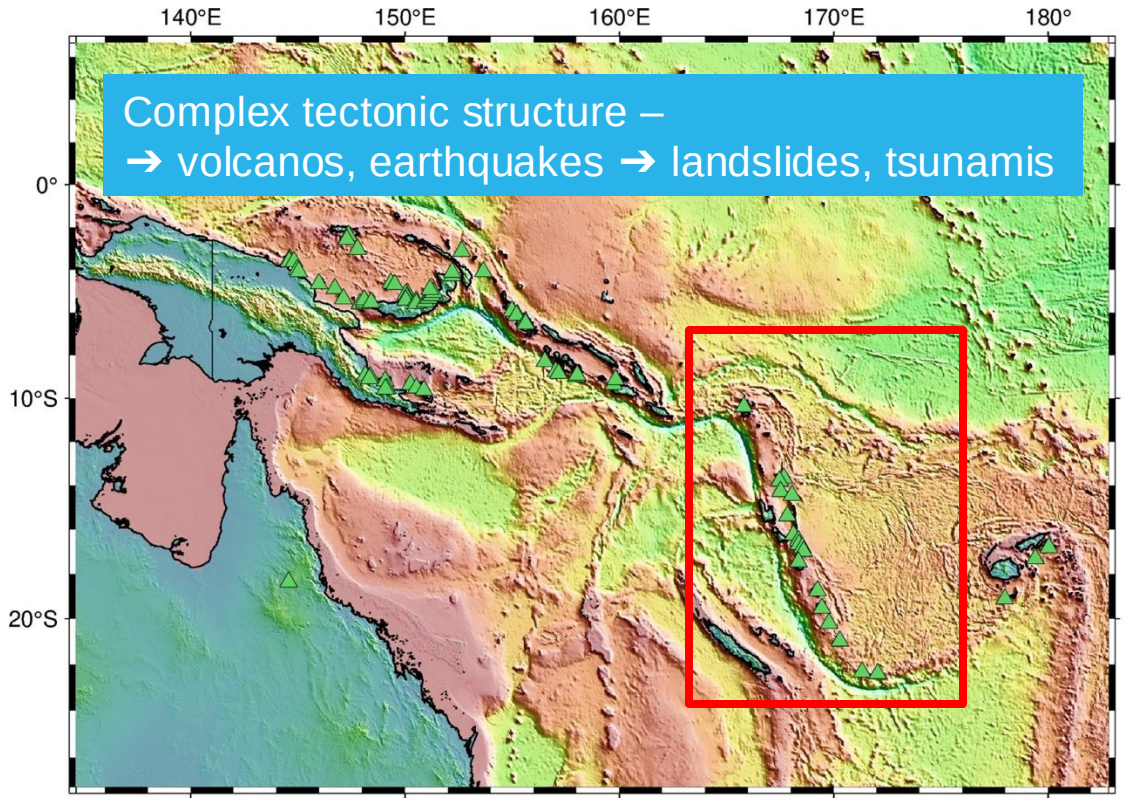
Tsunami warning time improvement obtained by CAM-2 sensors (white circles) compared to coastal tide gauge network (**green** triangles).



LEA; Matias et al., 2021

Tamtam SMART Cable System



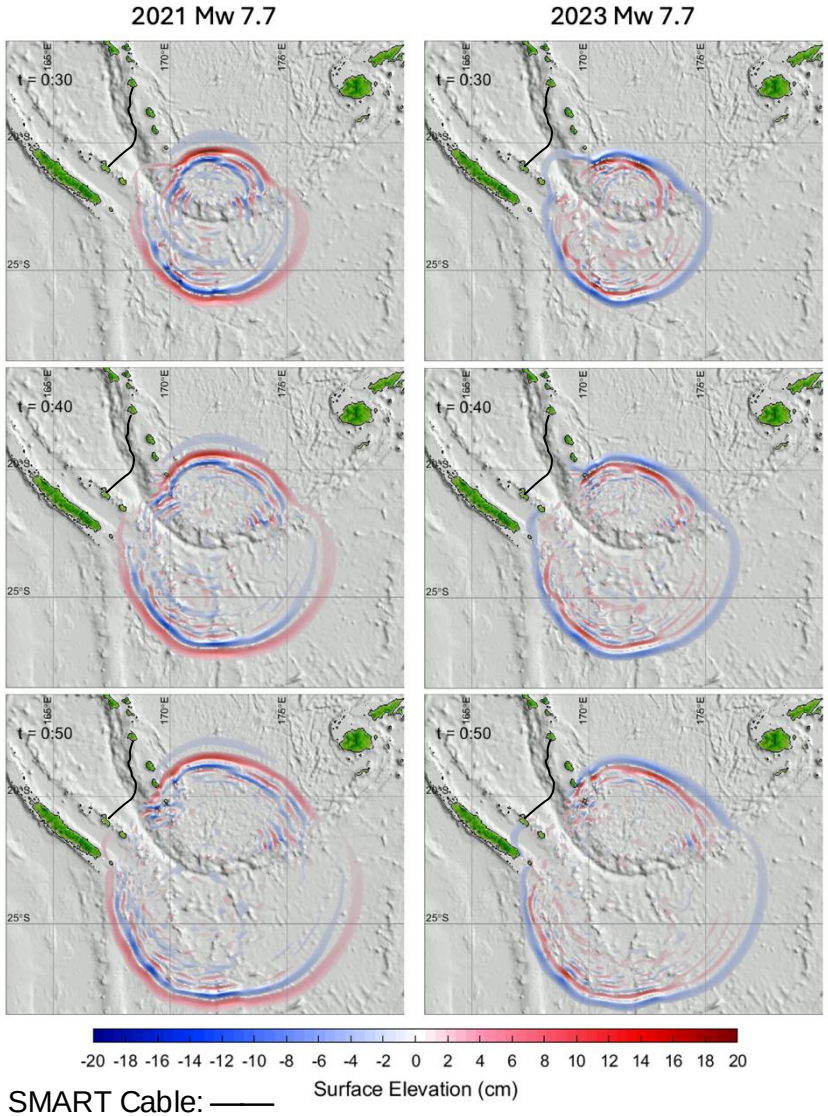


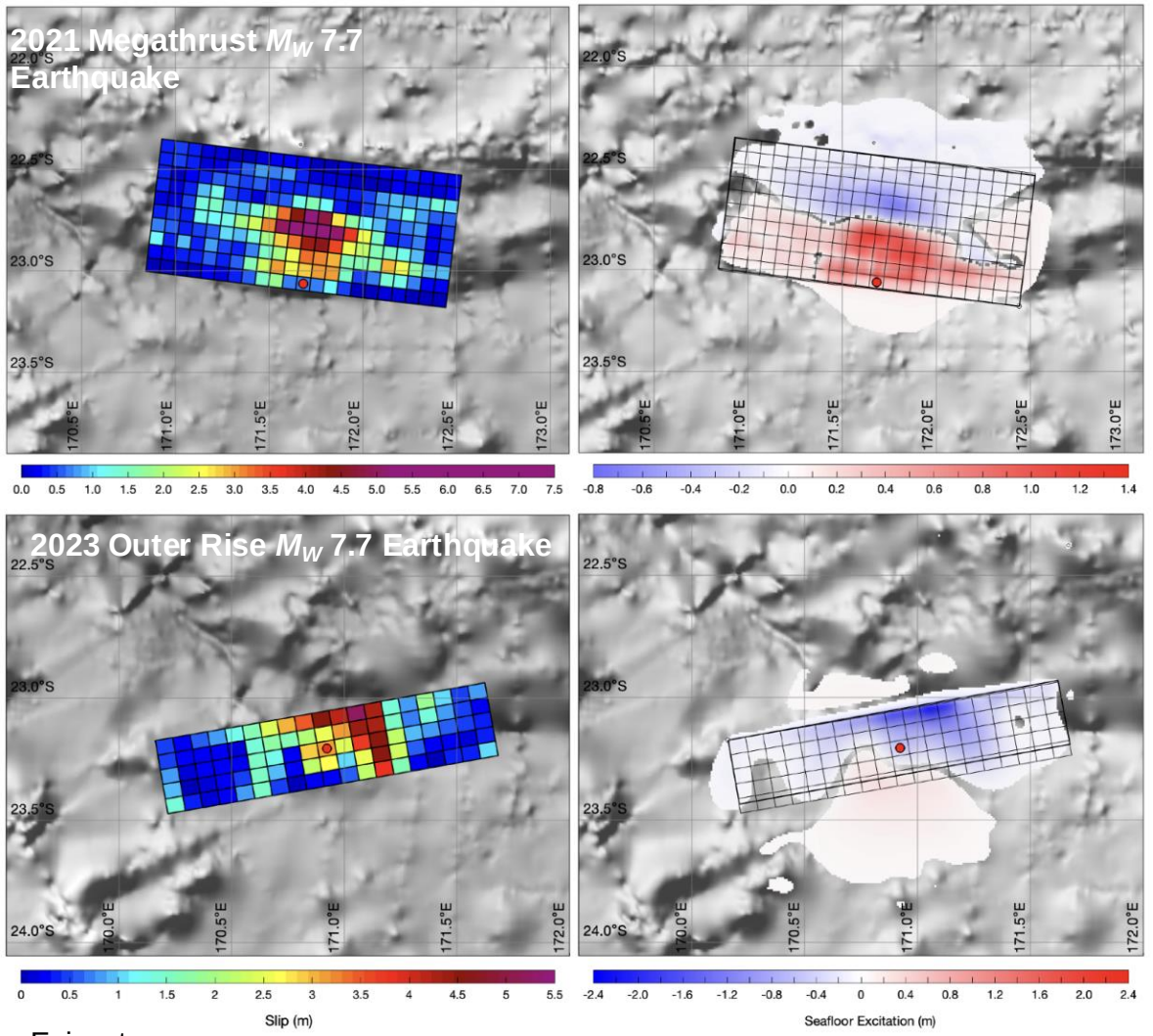
Vanuatu – more natural disasters than any other country
– typhoons, earthquakes, tsunamis, and volcanos – significant sea level rise.
SMART crucial to improve understanding and earthquake and tsunami EW.

Use Cases

2021 & 2023 M_W 7.7 Loyalty Islands Earthquakes

- Close proximity at the southern hook of the Vanuatu subduction zone
- Thrust vs normal faulting mechanisms in tsunami generation
- Source models from inversion of global seismic records and forward modeling of regional DART and tide gauge signals
- Non-destructive events as use cases for SMART cables





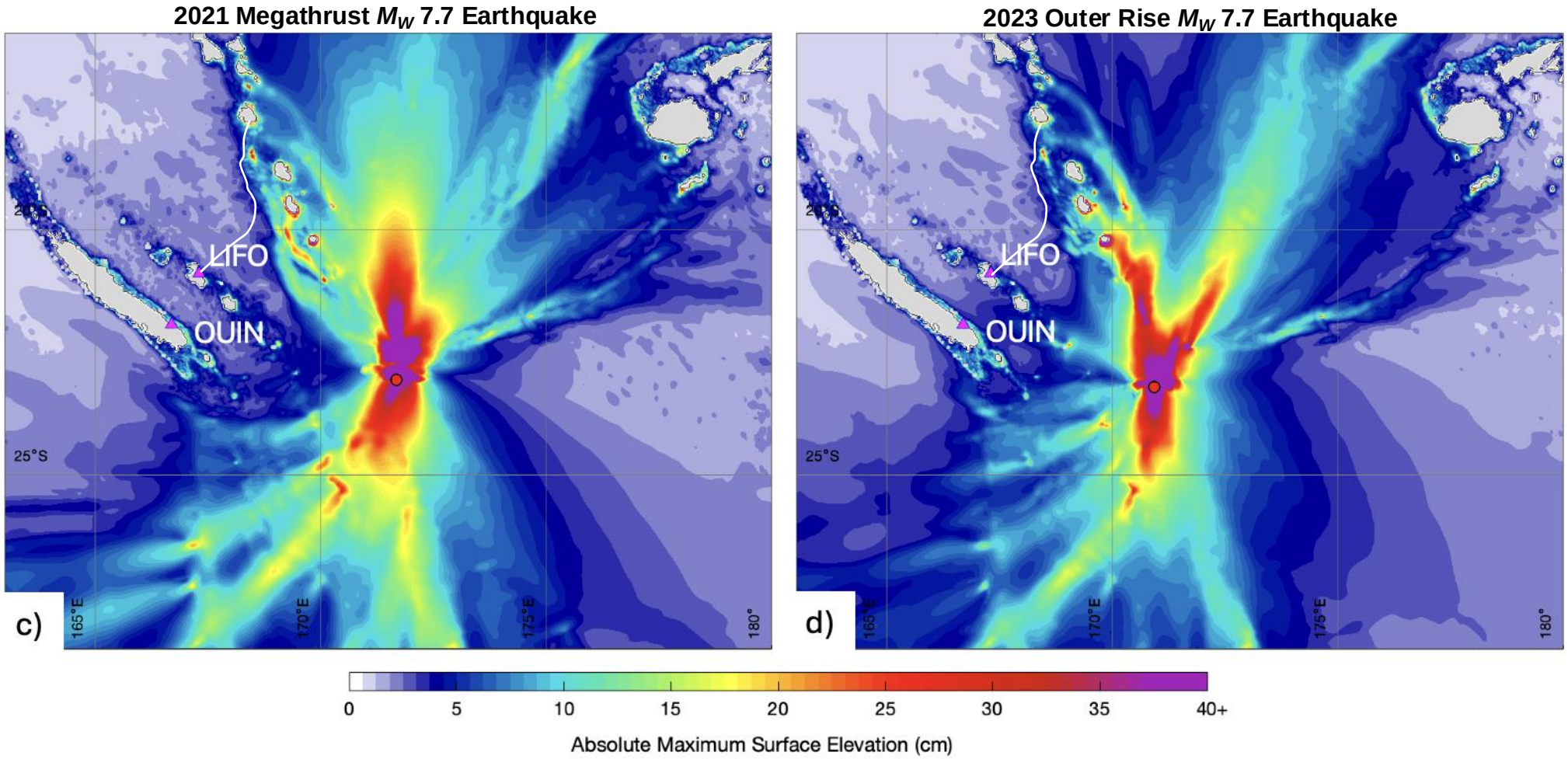
Use Cases – Cont.

Max Sea-surface Fluctuation

- Main energy in north – south directions due to fault orientation
- Northern lobes influenced by features along Hunter Ridge
- Southern lobes influenced by fault strike

Proposed SMART sensors

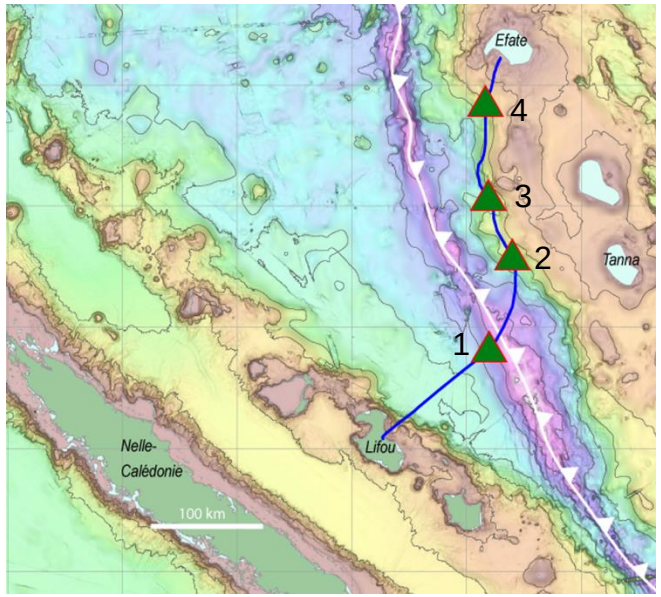
- Off insular shelves away from local amplification
- Generic tsunami readings with regional application

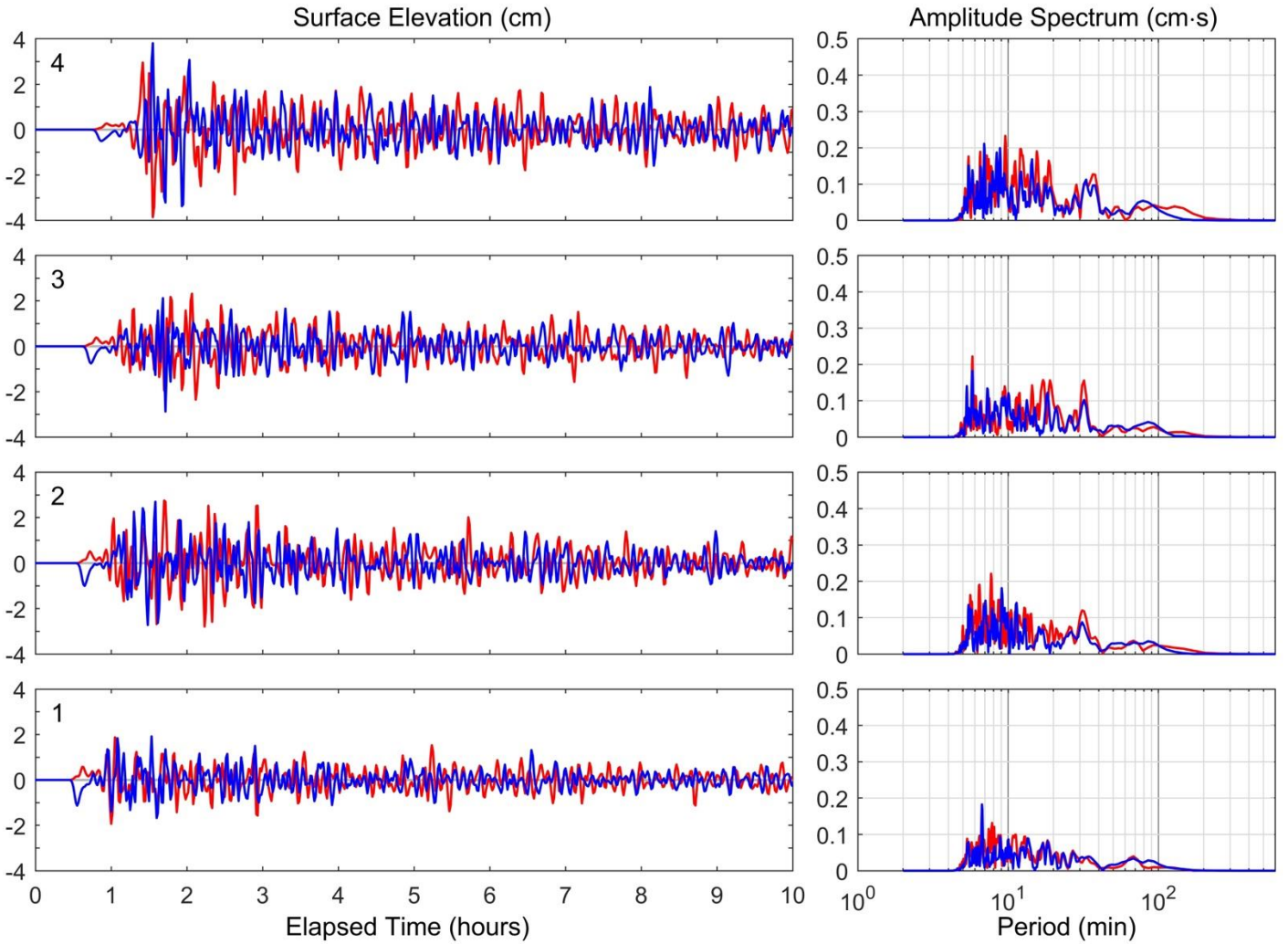


Use Cases – Cont.

Synthetic SMART sensor signals

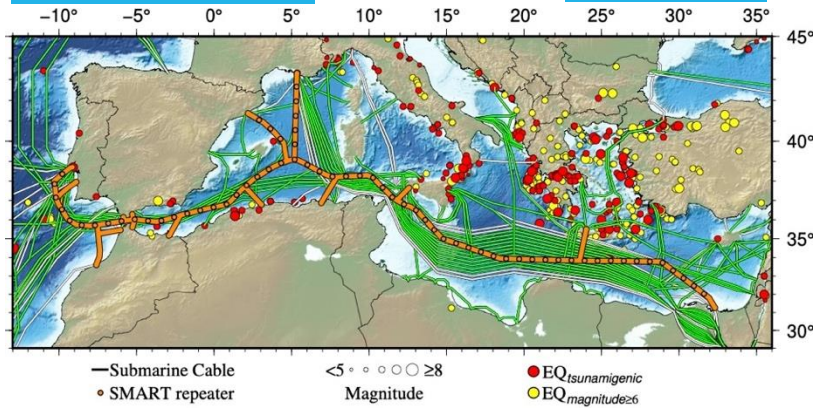
- A 10~20 conversion factor from sensor to regional tide gauge amplitudes (more modeling needed)
- Short lead time for warning in the near field, but supports confirmation of destructive or nondestructive events
- Continuous monitoring to confirm passage of most energetic waves
- Similar wave spectra of two distinct tsunamis suggesting resonance driven by bathymetry





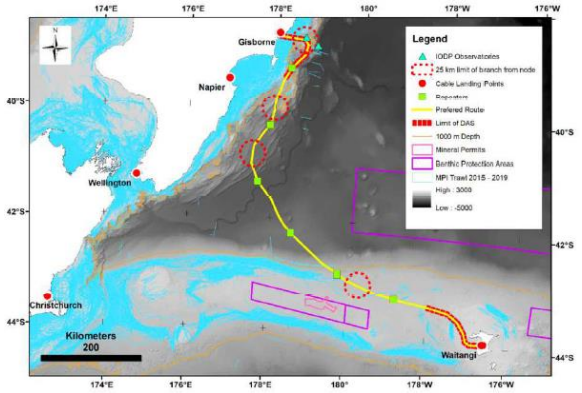
Systems in Play

Medusa



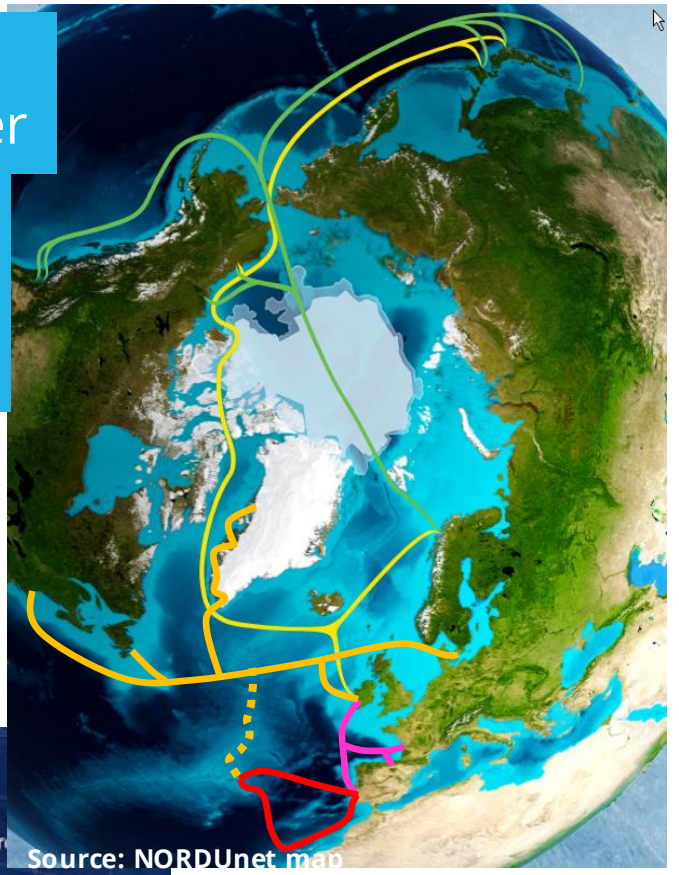
MISTS

NZ - Chathams



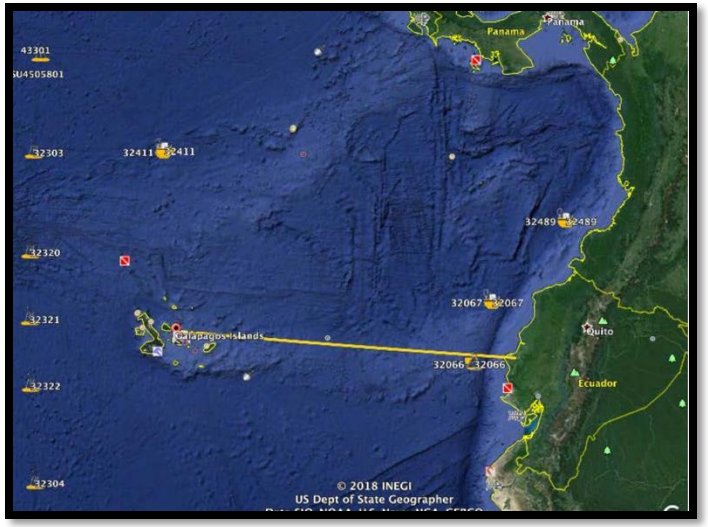
Polar Connect
Far North Fiber

Tusass
Pisces
CAM



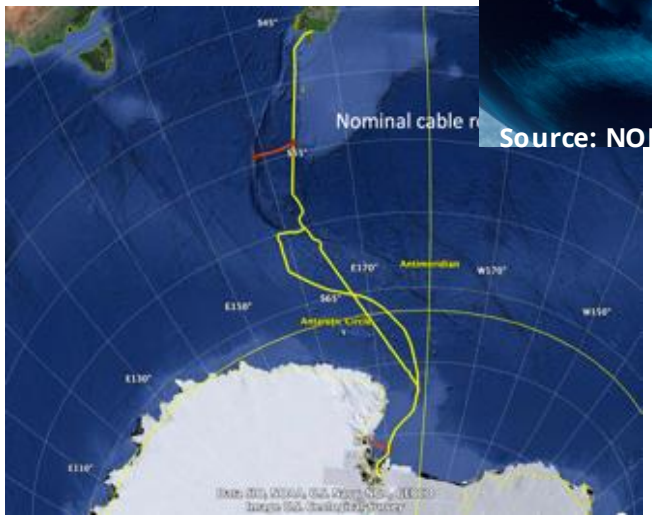
Source: NORDUnet map

Galapagos



Antarctica Chile

Antarctica US



Earth's Pulse: SMART Cables in Northern Hemisphere 4 October 2024

SMART CABLES

SMART Cables monitoring the North Pacific, Arctic and North Atlantic

Option 2:

Closing the gap to the North Atlantic, having Far North Fiber with a branch to the Azores + Pisces as a SMART Cable.

Systems:

- Polar Connect
- Far North Fiber
- Tusass
- Pisces
- Atlantic CAM

Source: NORDUnet map

ITU/WMO/UNESCO-IOC JTF SMART Cables

JTF SMART Cables has positive impacts:

- Improve earthquake and tsunami early warning
- Reducing time to activate national protocols with better event location parameters and in situ tsunami wave height, and to evaluate the cancellation/updates
- Improve the Global Ocean Observing System with new long-term data
- Improve the understanding of ocean currents and heat content and sea level rise for climate change (El Niño, coastal).
- Improve cable integrity – cables no longer “deaf, dumb and blind”
- Provide finance opportunity to the country for research.
- Legal and regulatory

Peru and SMART – CPPS GT-ATPS Report

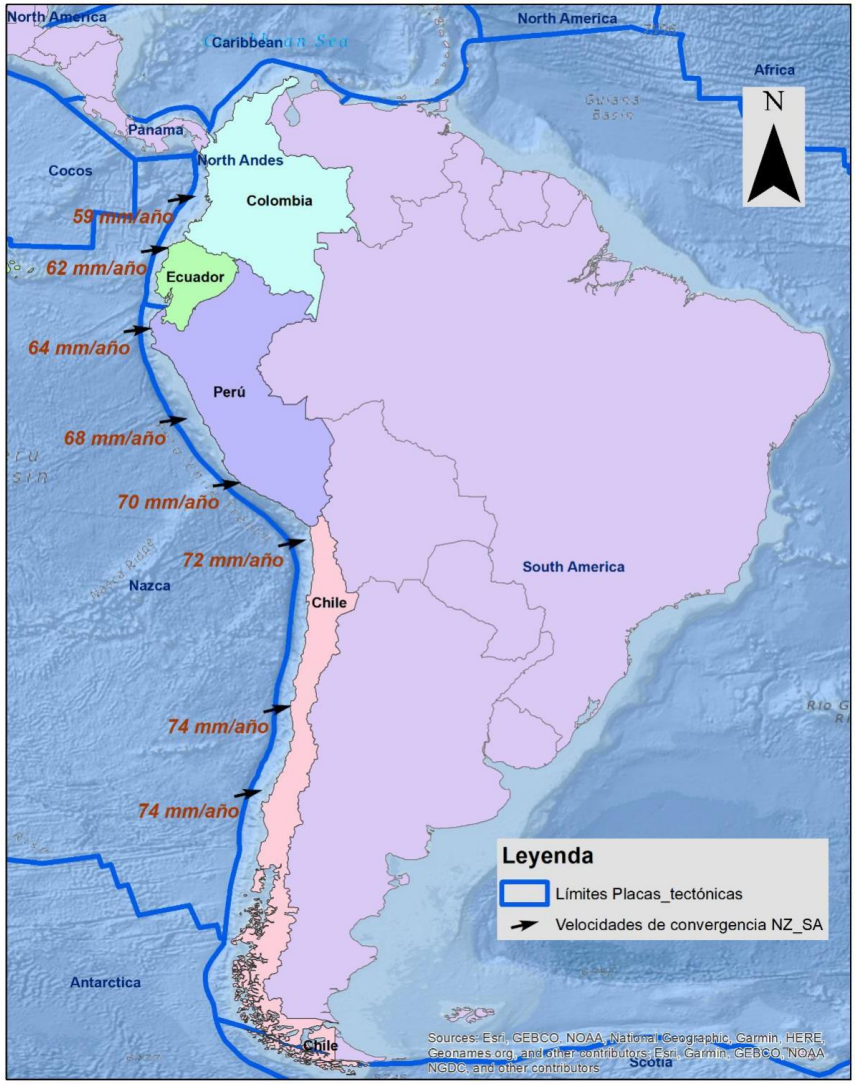
Capabilities for the evaluation of the threat of tsunamis for members of GT-ATPS and the exploratory proposal of opportunities and challenges for the incorporation of SMART cable technology. 2022

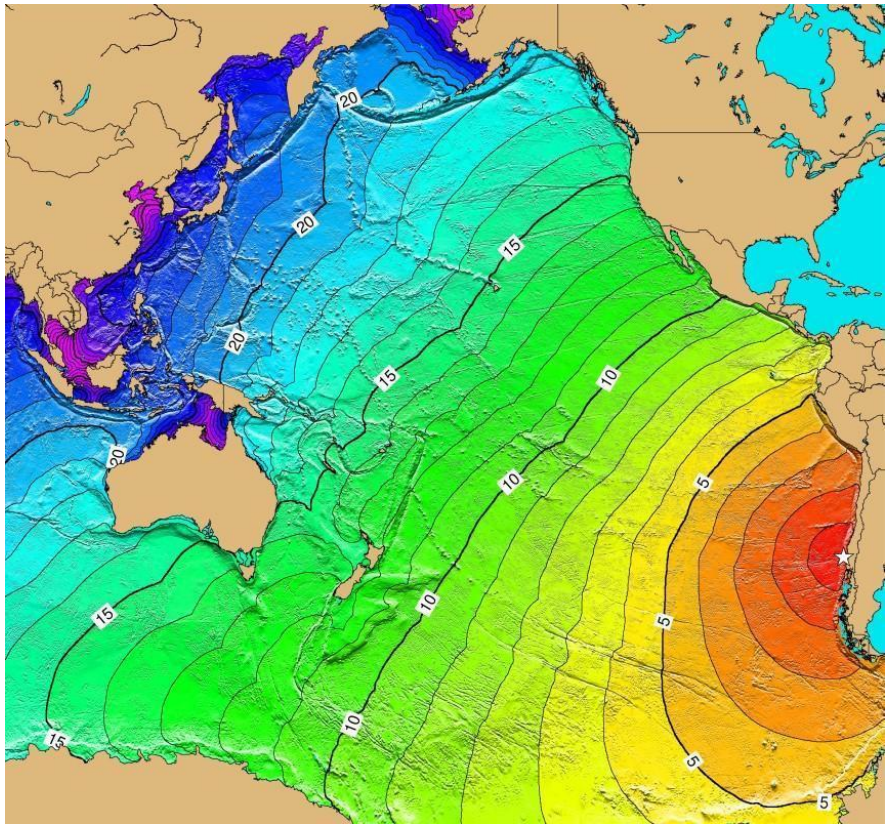
… implementation of oceanographic sensors in new underwater telecommunications cables, under the SMART concept (Scientific Monitoring and Reliable Telecommunications), is a promising solution to obtain a greater amount of data in real time that is essential to understand and manage urgent environmental issues such as climate change and the effects of tsunamis. Such sensors can provide important environmental data from sites in the deep ocean that would otherwise be difficult and expensive to obtain in real time and over large time scales.

Joint with South East Pacific Working Group, IOC ICG/PTWS

English version not yet distributed by IOC

Tectonics and Tsunamis





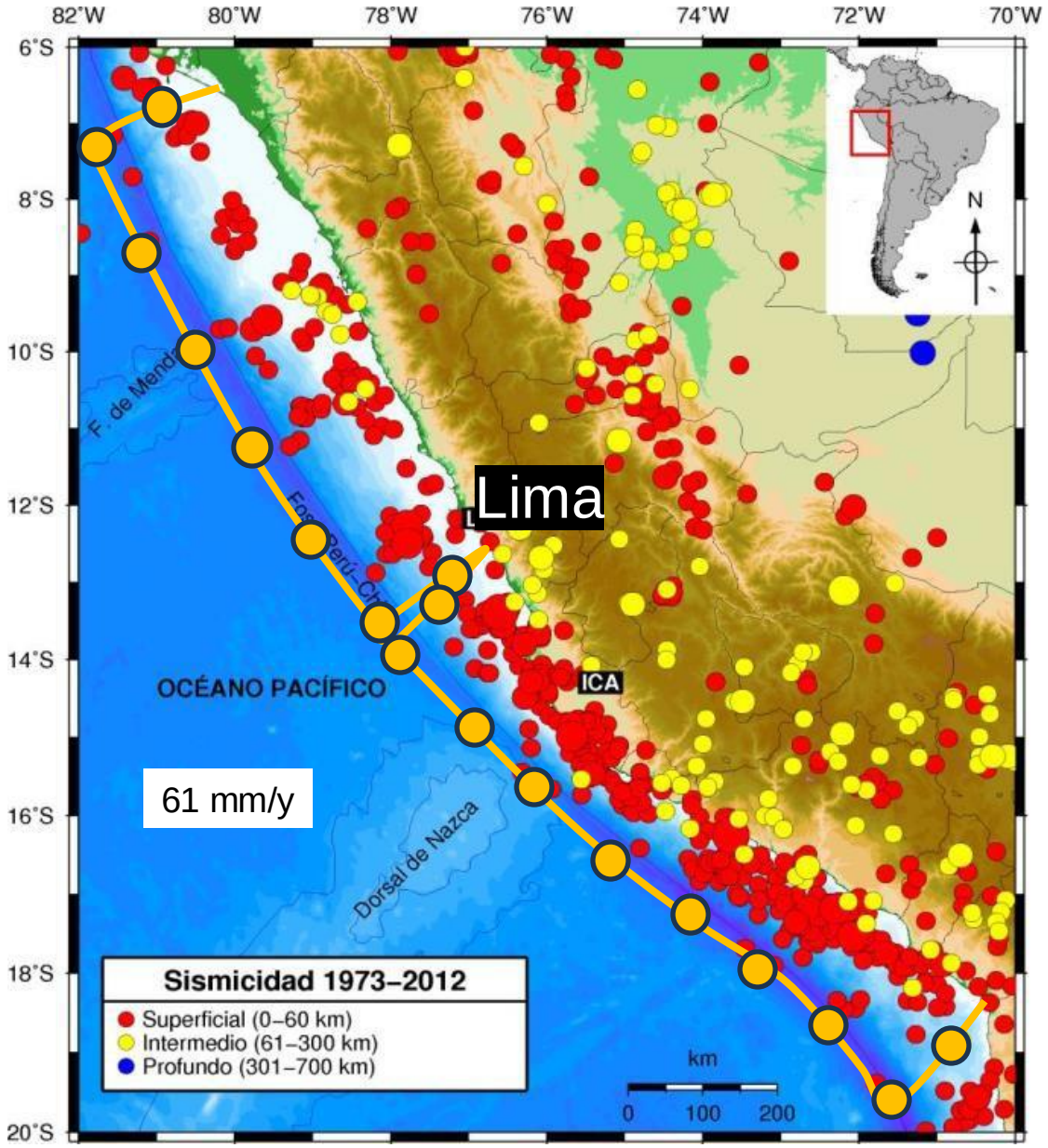
- Travel times from Chile 1960 M 9.5.

Recommendations and Opportunities

- From CPPS GT-ATPS Report
- Regional, multi-national
- SMART Cable
- 52 Sensor modules
- Spacing 120 km
- 5900 km
- Cost – cf Portugal

SMART = telecom + science/EW

Peru and SMART



1746 mega-thrust Lima–Callao earthquake, 90 km NW of Lima, destroyed

1970, Ancash, 70,000 dead, with landslide

Event	Fecha	Mw	Area de afectación
1	21/2/1996	7,5	Chimbote, Callao
2	11/12/1996	7,7	Chincha alta, Arica, Nazca, Marcona
3	23/06/2001	8,4	Ocoña, Camaná, Quilca, Matarani, Tacna
4	15/08/2007	8,0	Nazca, Pisco, Lima

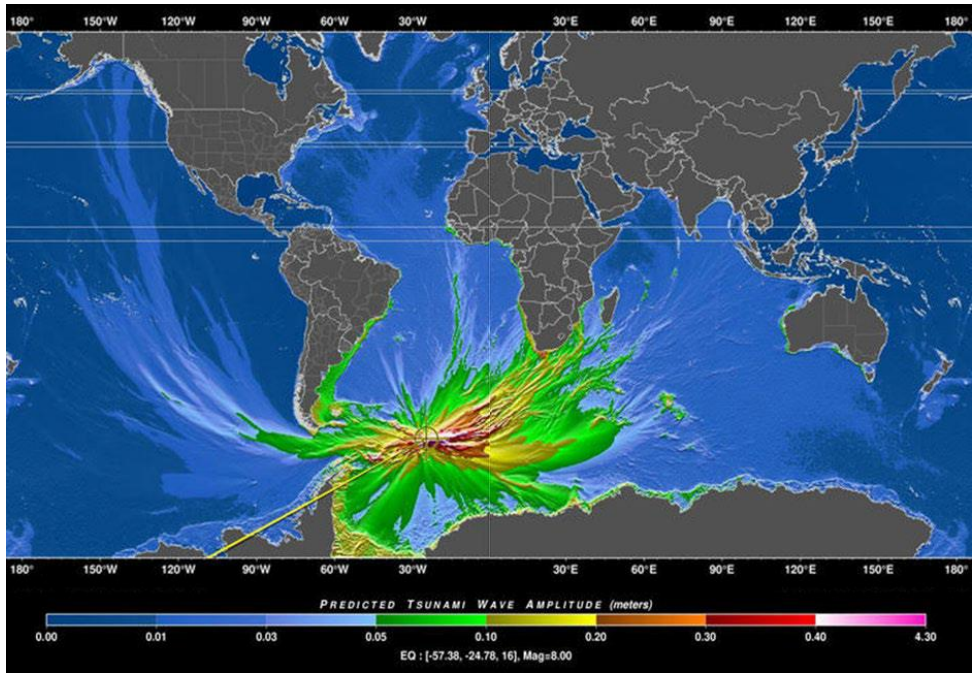
2007 off Lima, 39 km deep, 3.5 minutes, severed EQ damage, 514 deaths, tsunami 3 deaths, 7 m runup

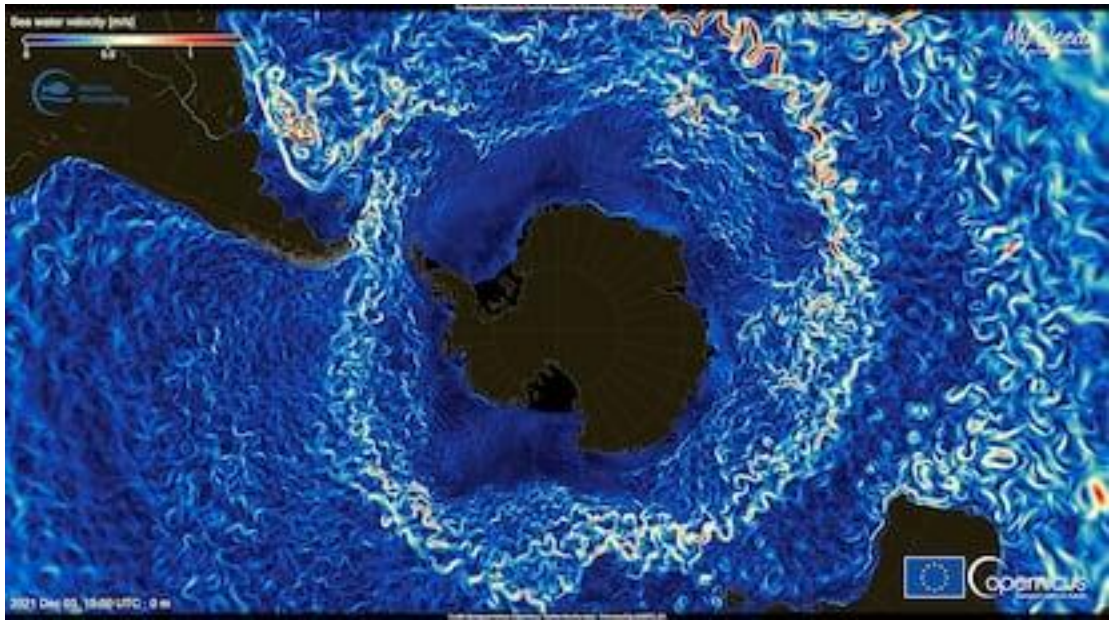
Possible SMART Cable
Needs telecom partners!

Drake Passage - Antarctica

- **Proposals for Drake Passage cable started 2018**
- **Chile Subtel RfT for Feasibility Study – 2025, includes SMART**
- **The #1 location in the world for a SMART cable for climate**
- **Antarctic Circumpolar current – VERY important for climate**
- **Tsunami risk, local and regional**

MUST be International!





2021 Antarctic Subsea Cable Workshop
High-Speed Connectivity Needs to Advance US Antarctic Science

National Science Foundation

DESKTOP STUDY

Exploring the Feasibility of a Science Monitoring And Reliable Telecommunications (SMART) Fiber Optic Cable System Connecting

ANTARCTICA
AUSTRALIA
NEW ZEALAND

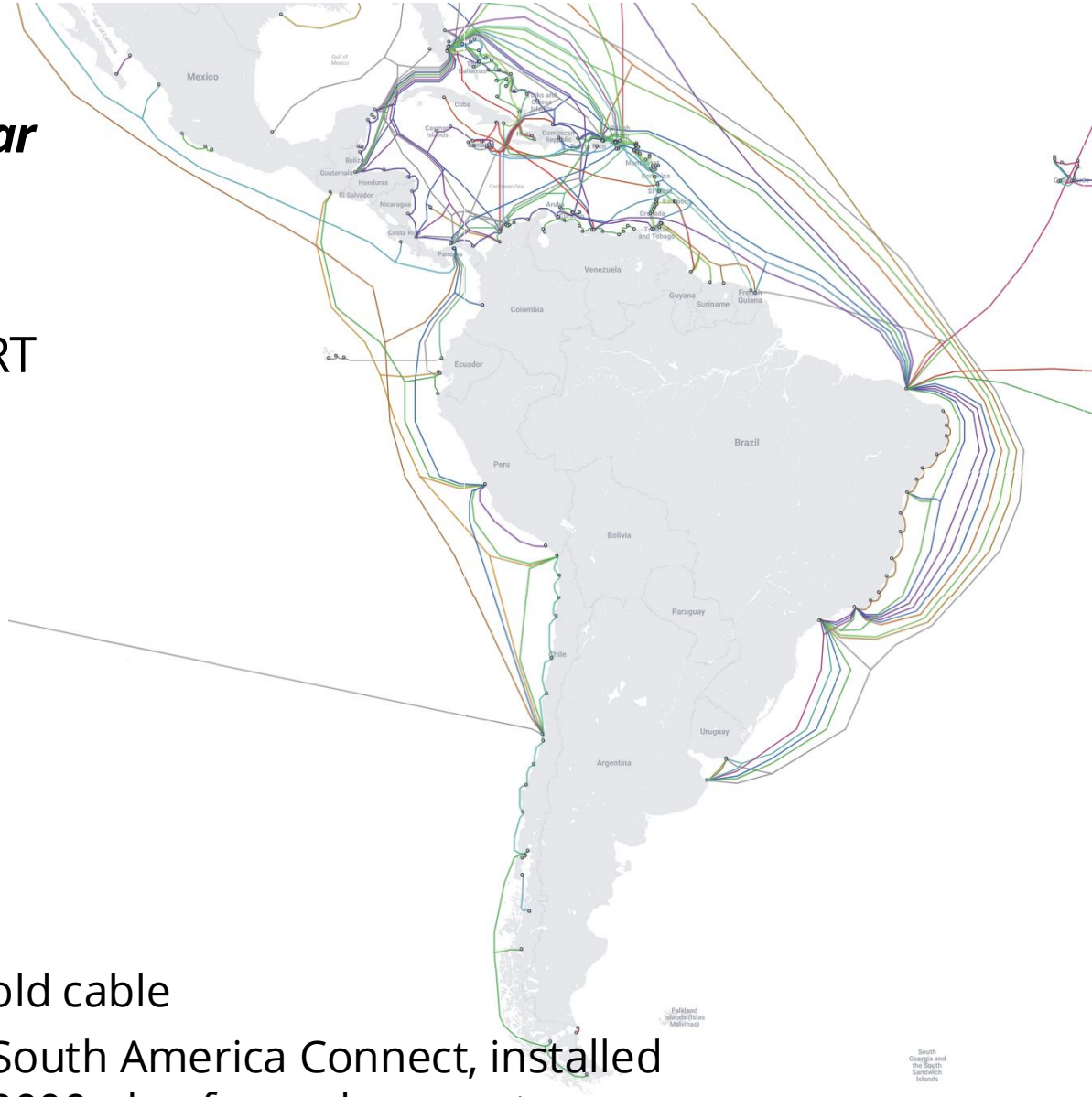
August 2022

Opportunities

- ***Cable system design life 25 years - retire***
- ***Always new cables, new routes ~50-100 K km/year***
- ***Future cable possibilities globally***
- Working to include SMART capability
- Let's work together to make future projects SMART

What can we do?

- Dialogue between government and subsea telecom industry
- Address mutual benefits between all stakeholders to promote SMART
- Engage local science and academic communities with the global perspective of SMART.
- Internal coordination and discussion
- ➔Working group to carry forward



An old cable

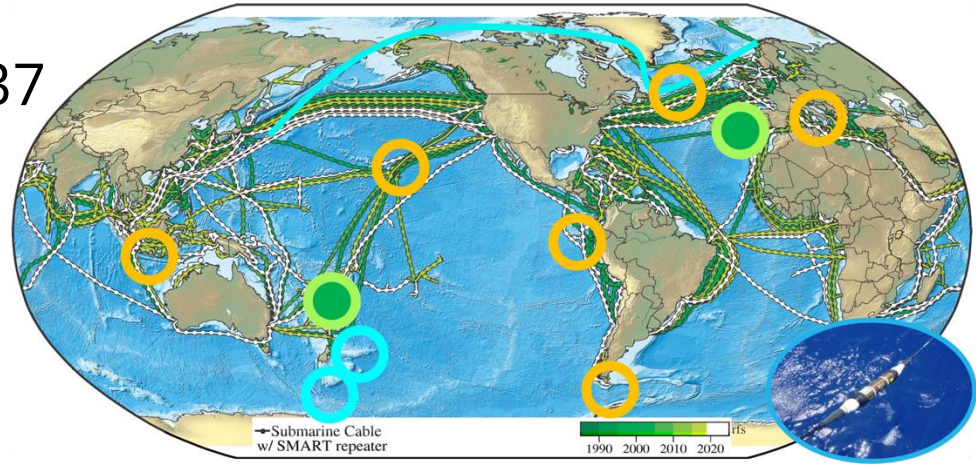
- South America Connect, installed 2000, due for replacement

Concluding Remarks

Global Array: Climate, Oceans, Sea Level, Earthquakes, Tsunamis

Create a Planetary sensor, power, Internet network

- SMART – marriage with telecom – connectivity, climate, DRR – three for the price of one – saves on all fronts
- Anticipated additional 1.3 Gm of cable in water by 2037
- Leverage annual investment ~ $ 5 Billion
- 25+ year life, highly reliable, low lifetime cost
- Recent successes – set precedents for future systems
- Challenges: $, tech, data, permitting, legal, security, …
- EU Funding: Cables w/ SMART
- Working with GOOS, Tsunami, Ocean Decade, DOOS, RENs
- Think globally, act locally!
- Good opportunity for Peru to lead!



Saving Lives

Still much to achieve

PTWS Joint WG2 – TT-ISN and TT-FOO

Points:

- Under novel technologies – TRL? Time to operational status? SoPs?
- Essential - Framework for multi-sensor forecasting using synthetics – and real data!!! (Kalman filter like – learn from operational numerical weather forecasting, climate and ocean modelling data assimilation)
- Multi-data utilisation - using multi-data to reduce uncertainty; and using multi-data to generate forecasts
- Help with prospective systems – quantify benefits (e.g., SEPac study, Indonesia, Vanuatu, Portugal)
- Improve interaction with other ICG equivalent groups
- Improve interaction with GOOS – IOC and WMO

PTWS Joint WG2 – TT-ISN and TT-FOO

ISN

- Active watch and stocktake of technologies – JTF Sensor Review Working Group
- Data – begs question of interaction with GOOS, WMO WIS2.0, etc.
- Encouraging data optimisation of those observations for forecasting – Data assimilation
- Help members quantify the capability of sensor networks (integrated) at regional scales in terms of early warning times.
- Consider multi-hazard – including climate - GOOS

FOO

- Understanding how current forecasting systems improved with new data that is fundamentally already in-use, or close-to-use (e.g., SMART, seismic, absolute ocean amplitude; altimetry);
- Data from new and existing data streams can:
- Feed into TT-ISN, the link between the development of novel observation approaches and tsunami warning and forecasting applications – for ISN to engage with observation generators.

SMART CABLES

PTWS Joint WG2-TT-ISN and TT-FOO
16 September 2024
Honolulu, Hawaii

SMARTCables.org

ITU/WMO/UNESCO IOC Joint Task Force

Scan to Join!

Danke Gracias Thank you Merci Tankyu tumas
Arigatō Xièxiè Terima kasih Takk Grazie
Mālō 'aupito Kop koon Salamat po S' efharistó